



Standard Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter¹

This standard is issued under the fixed designation E 1474; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This test method provides a means for measuring the ignition time and heat release of the composite upholstered components of upholstered furniture and mattresses using an oxygen consumption calorimeter.

1. Scope

1.1 This fire-test-response test method can be used to determine the ignitability and heat release from the composites of contract, institutional, or high-risk occupancy upholstered furniture or mattresses using a bench scale oxygen consumption calorimeter.

1.2 This test method provides for measurement of the time to sustained flaming, heat release rate, peak and total heat release, and effective heat of combustion at a constant radiant heat flux of 35 kW/m². Heat release data at different heating fluxes may also be obtained by this test method. The specimen is oriented horizontally, and a spark ignition source is used.

1.3 The times to sustained flaming, heat release, and effective heat of combustion are determined using the apparatus and procedures described in Test Method E 1354.

1.4 The tests are performed on bench-scale specimens combining the furniture or mattress outer layer components. Frame elements are not included.

1.5 This test method should be used to measure or describe the responses of materials, products, or assemblies to heat and flame under controlled conditions and should not be used to describe or appraise the fire hazard or fire risks of materials, products, or assemblies under actual fire conditions. However, the results of the test may be used as elements of a fire hazard assessment or a fire risk assessment that takes into account all of the factors that are pertinent to an assessment of the fire hazard or fire risk of a particular end use.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see Section 6.

2. Referenced Documents

2.1 ASTM Standards:

D 123 Terminology Relating to Textiles²

E 176 Terminology of Fire Standards³

E 1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter³

2.2 Other Documents:

CA TB 133, Flammability Test Procedure for Seating Furniture for Use in Public Occupancies⁴

ISO 5725 Part 2, Accuracy (Trueness and Precision) of Measurement Methods and Results—Basic Method for the Determination of Repeatability and Reproducibility of a Standard Measurement Method⁵

3. Terminology

3.1 *Definitions*—For definitions of terms relating to this test method refer to Terminology D 123 and E 176.

3.1.1 *effective heat of combustion, n*—the amount of heat generated per unit mass lost by a material, product, or assembly, when exposed to specific fire test conditions. (see *gross heat of combustion*.)

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² *Annual Book of ASTM Standards*, Vol 07.01.

³ *Annual Book of ASTM Standards*, Vol 04.07.

⁴ Available from State of California, Dept. of Home Furnishings and Thermal Insulation, North Highlands, CA 95660-5595.

⁵ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

3.1.1.1 *Discussion*—The effective heat of combustion depends on the test method and is determined by dividing the measured heat release by the mass loss during a specified period of time under the specified test conditions. Typically, the specified fire test conditions are provided by the specifications of the fire test standard that cites effective heat of combustion as a quantity to be measured. For certain fire test conditions, involving very high heat and high oxygen concentrations under high pressure, the effective heat of combustion will approximate the gross heat of combustion. More often, the fire test conditions will represent or approximate certain real fire exposure conditions, and the effective heat of combustion is the appropriate measure. Typical units are kJ/g or MJ/kg.

3.1.2 *oxygen consumption principle, n*—the expression of the relationship between the mass of oxygen consumed during combustion and the heat released.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *heating flux, n*—the prescribed incident flux imposed externally from the heater onto the specimen at the initiation of the test.

3.2.2 *heat release rate, n*—the heat evolved from the specimen, expressed per unit area of exposed specimen area per unit of time.

3.2.3 *ignitability, n*—the propensity for ignition, as measured by the time to sustained flaming at a specified heating flux.

3.2.4 *mattress, n*—a mattress is a ticking (outermost layer of fabric or related material) filled with a resilient material, used alone or in combination with other products, intended or promoted for sleeping upon.

3.2.5 *net heat of combustion, n*—the oxygen bomb calorimeter value for the heat of combustion, corrected for the gaseous state of product water.

3.2.6 *orientation, n*—the plane on which the exposed face of the specimen is located during testing, which is horizontal facing up for this test.

3.2.7 *sustained flaming, n*—the existence of flame on or over the surface of the specimen for a period of 4 s or more.

3.2.8 *upholstered, adj*—covered with material (as fabric or padding) to provide a soft surface.

4. Summary of Test Method

4.1 This test method is based on the observation that the net heat of combustion is generally directly related to the amount of oxygen required for combustion (1).⁶ Approximately 13.1×10^3 kJ of heat is released per 1 kg of oxygen consumed. Specimens in the test are burned in ambient air conditions while being subjected to a prescribed external heating flux of 35 kW/m².

4.2 The heat release is determined by measurement of the oxygen consumption, as determined by the oxygen concentration and flow rate in the combustion product stream, as described in Test Method E 1354.

4.3 The primary measurements are oxygen concentration and exhaust gas flow rate. Additional measurements include

the mass loss rate of the specimen, the time to sustained flaming, and the effective heat of combustion. Ignitability is determined by measuring the time from initial exposure to the time of sustained flaming of the specimen.

5. Significance and Use

5.1 This test method is used to determine the time to sustained flaming and heat release of materials and composites exposed to a prescribed heat flux in the cone calorimeter apparatus.

5.2 Quantitative heat release measurements provide information that can be used for upholstery and mattress product designs and product development.

5.3 Heat release measurements provide useful information for product development by yielding a quantitative measure of specific changes in fire performance caused by component and composite modifications. Heat release data from this test method will not be predictive of product behavior if the product does not spread flame over its surface under the fire exposure conditions of interest.

5.4 *Test Limitations*—The test data are invalid if either of the following conditions occur: (1) explosive spalling; or (2) the specimen swells sufficiently prior to ignition to touch the spark plug, or the specimen swells up to the plane of the heater base during combustion.

6. Safety Precautions

6.1 The test procedures involve high temperatures and combustion processes. Hazards may therefore exist for burns, ignition of extraneous objects or clothing, and inhalation of combustion products. The operator must use protective gloves for insertion and removal of the test specimens. Neither the cone heater nor the associated fixtures should be touched while hot, except with the use of protective gloves.

7. Test Specimen Preparation—Method A (2)

7.1 *Equipment and Supplies for Specimen Preparation:*

7.1.1 *Cutting Equipment*—Cut foams with a band saw; a foam-cutting blade shall be used. This blade has no teeth; instead, it has a wavy scallop to the edge. Ensure that the blade is well sharpened. Make certain that no silicones or other oils are applied to lubricate the blade; lubrication shall be solely with graphite or molybdenum compounds. The band saw blade must make a straight and true cut of the foam. Set the blade guide no higher than 12 mm above the stock to be cut.

7.1.2 *Forming Blocks*—The specimen preparation rests crucially upon the proper use of forming blocks. These blocks are made in dimensions of 98 by 98 by 50 mm. Each of these dimensions shall be controlled to ± 0.5 mm. Use, as the material for the forming blocks, a dense wood, such as maple, which is minimally subject to dimensional changes when the humidity is changed. Do not use pine. Use only fully kiln-dried timber for making the forming blocks. Ensure that all surfaces are cut straight and true and are smooth. The edges shall not be rounded, but the corners shall be slightly rounded. It is preferable to lacquer the blocks with an acrylic lacquer to ensure a hard, smooth, stable surface. Make up a minimum of 12 blocks to allow a reasonable number of specimens to be prepared at the same time.

⁶ The boldface numbers in parentheses refer to the list of references at the end of this test method.

7.1.3 *Adhesive*—Several adhesives have been found suitable for securing the fabrics. The adhesive shall be low in flammability and shall have suitable holding power to permit inserting the resilient padding, stay in place until the testing is performed (that is, through the required conditioning) and during the flammability test procedure. For the latter, the glued portions of the fabric shall neither flame excessively nor retard burning. Adhesives that are based on polychloroprene, acrylic, or water have been found suitable.

7.1.3.1 *Adhesive Selection*—Adhesives based on polychloroprene in methylene chloride solvent have been found suitable for all composites tested.⁷ Adhesives based on acrylic in water solvent (white glue, readily available in hardware and craft stores)⁸ have been proven adequate for many, but not all, fabrics and interliners tested by a United States testing laboratory. Other adhesives are also suitable, provided they meet the stated requirements.

7.1.3.2 *Adhesive Application*—The method of adhesive application depends on the particular adhesive selected. Water-soluble adhesives are applied directly from the bottle and therefore do not require a brush. Likewise, any spillage is readily cleanable with water. This type of adhesive does not set as quickly as the solvent-based adhesives, which permits shifting the fabric as necessary to create a neat, tight package. However, the glued specimen shall be left overnight to ensure a good seal. On the other hand, polychloroprene-based adhesives are applied with a brush made of hog bristles or other stiff, course material. The brush shall be flat and square cut, with a width of 7 to 8 mm. A solvent compatible with the adhesive shall be used for cleanup and storage of the brush. The solvent-based glues set up very quickly and do not permit any adjustment around the wood block.

7.1.3.3 *Adhesive Checking*—To test the efficiency of an adhesive, apply a small amount on two small pieces of the fabric or interliner to be used. Allow the adhesive to dry (at least overnight), and then attempt to tear the fabric pieces from one another. To be acceptable, the glued pieces shall not be able to be separated without tearing the fabric.

7.1.4 *Tape*—Masking tape or other tape with adhesive is used to assist in assembling the test composites. Any type of tape which will adequately adhere to all fabrics and be easy to remove after completion of assembly is suitable for this purpose. Some interliners or fabrics will be damaged by direct application of masking tape to their surface, since removal results in tearing or marring the surface. For items susceptible to such damage, prepare strips of paper slightly wider than the width of the masking tape and long enough to reach all the way around the forming block. Then secure the paper strips with tape.

7.1.5 *Aluminum Foil*—Use aluminum foil that is 0.03 to 0.04 mm thick.⁹ No other foil thickness shall be used; it is especially important not to substitute a thicker foil.

7.2 Basic Preparation of Specimens:

7.2.1 The basic instructions here pertain to specimens which comprise only a single layer of fabric over a single layer of resilient padding. The same instructions apply to specimens where an interliner is laminated onto the back of the fabric; in the latter case, the fabric/interliner combination is simply treated as a fabric alone. For specimens which use multiple padding layers, separate interliner layers and other more specialized constructions. Supplemental instructions are given in 7.3.

7.2.2 *Cutting of Resilient Padding Blocks*—The thickness of the resilient padding block will normally be 50 mm when a single layer of resilient padding is the only padding material used in the composite. With a typical fabric thickness, this will result in a total specimen thickness of approximately 50.9 mm, which is acceptable. Each resilient padding block shall be cut square, with 90° corners and face dimensions of 102.5 ± 0.5 by 102.5 ± 0.5 mm. This size ensures that the resilient padding will be compressed during composite assembly, leading to tight, well-formed specimens.

7.2.2.1 Some resilient paddings have a tendency for high friction against the sawing table and the guide. To make a smooth cut by allowing the resilient padding to slide easier, put a piece of paper between the resilient padding and the table/guide. Push the assembly of resilient padding and paper forward and allow the blade to cut through both the resilient padding and the paper.

7.2.3 *Forming Resilient Padding Blocks*—The cone calorimeter test results will not be repeatable if the density of the resilient padding tested is not very closely controlled. For this purpose, each batch of resilient padding specimens prepared shall be checked for mass. It is assumed here that three replicate tests will be performed for each specimen type. Therefore, once three blocks of resilient padding have been cut, the mass shall be determined. No block shall have a mass of more than 105 % of the mean of the three masses, nor a mass of less than 95 %. If such a difference occurs, additional blocks shall be cut and the mass determined. The preparation of composites cannot start until three blocks of resilient padding which conform to the above 5 % deviation limit have been obtained. The blocks accepted shall be marked so as to be traceable. The mass of each block of resilient padding shall be noted along with the identification marks of the blocks. The mass of resilient padding shall be reported in the test report along with other information about this test run.

7.2.4 Fabric Cutting:

7.2.4.1 First, cut a square of 200 by 200 mm.¹⁰

7.2.4.2 For cone calorimeter results to be repeatable, fabric for the different replicates shall show uniformity. When fabric material is obtained directly from a bolt of cloth, do not cut specimens using closer than 10 to 12 cm to the selvedge (that is, the finished edge).¹¹

7.2.4.3 To assist in verifying that uniform specimens have been cut, check each set of fabric specimens that has been cut

⁷ Parabond A-1535 obtained from Para-Chem Southern, Inc., Simpsonville, SC is an example of a suitable adhesive of this type.

⁸ DAP Weldwood, Hobby'n Craft Glue is an example of a suitable adhesive of this type.

⁹ Commercially available heavy duty foil has the appropriate thickness.

¹⁰ Do not cut fabrics on the bias. If the fabric weave is such that the yarns in the two directions do not lie at 90° to each other, do not cut the sample along yarns in both directions since a skew specimen would result.

¹¹ This is because sometimes there are weaving or coating variations that occur closer to the selvedge.

to the 200 by 200 mm size for mass. Determine the mass once three replicate pieces have been cut. None of the pieces shall have a mass of more than 105 % of the mean of the three, nor a mass of less than 95 %. If such a difference occurs, check to see if any of the pieces have been cut oversized; trim them if this is found to be the case. If the cause of variation was not due to oversized pieces, then additional fabric pieces shall be cut and the mass determined.

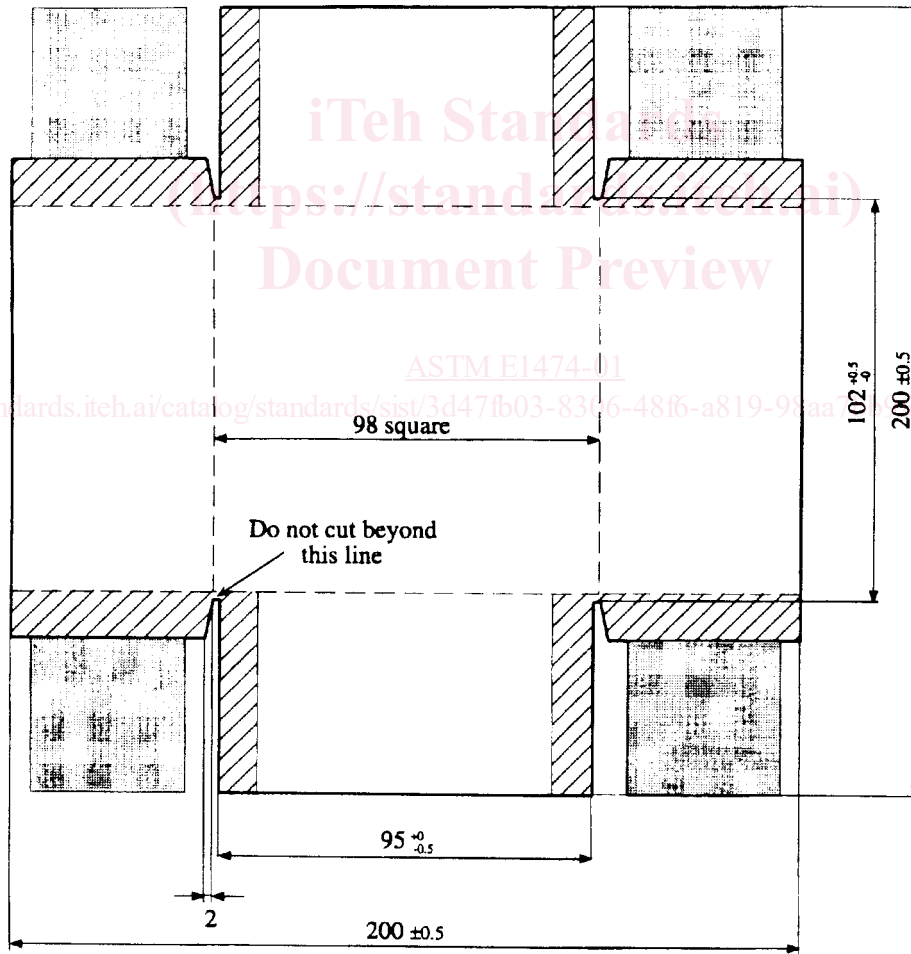
7.2.4.4 If fabrics cannot be prepared to within the 5 % deviation limit, note the fabric masses and mass range of the specimen. Continue cutting the fabric for each specimen by cutting it to the shape indicated in Fig. 1. All given dimensions shall be controlled in accordance with the tolerances given in the figure (± 0.5 mm). Only essential dimensions are given in the figure. The 95 and 102 mm dimensions shall be checked both before and after cutting. When a fabric having thick yarns is cut, stop cutting outside the 102 mm dimension when a yarn is reached. Do not cut through the yarn if this will make the dimension smaller than 102 mm.

7.2.5 Preparing the Fabric Shell:

7.2.5.1 Assemble the finished shell upside-down upon a forming block. Place the fabric, top side down, on the table. Place the block on top, making sure that it is well centered. Bend up the two short sides. Tape each of these sides on to the top of the forming block in the center of the top edge. Bend up the long sides and also tape them to the top of the block. Make sure that the fabric does not slip sideways on the block by checking all four corners of the top face. The fabric shall be snug but not stretched.

7.2.5.2 For sensitive interliners, when paper strips are used, put two strips, forming a cross, under the fabric before placing the forming block on top of it.¹² When the fabric is bent up, allow the strips to follow. Secure the paper strip with masking tape to hold it on. Turn the block to stand on one of its short side faces. Using the suitable adhesive, glue down the 10 mm gluing area marked with stripes in Fig. 1 on each corner flap

¹² Make the paper strips wider than the tape, but shorter, so the tape can adhere to the wood block or to itself.



 Gluing area
 To be cut off after gluing
 Dimensions in mm

FIG. 1 Fabric Cutting Shape

(the area that corresponds to the long side) onto its mating short-side surface. Apply adhesive both to the underneath surface of the flap and to the surface against which it will mate. Use of a 7 to 8 mm wide brush (for solvent based adhesives) will ensure that the glued area is approximately 10 mm wide. Press down immediately after applying the adhesive or after waiting to dry, as appropriate, according to the instructions of the adhesive manufacturer.

7.2.5.3 The grey area shown in Fig. 1 is used for gripping and stretching the fabric around the corners of the forming block. After applying adhesive to the first two corners, turn the block to rest on the side just glued and apply adhesive to the other two corners. If necessary, tape over the gripping handles and around the corners in order to secure the fabric in the shape of the forming block (see above), or wrap the block with paper strips prior to sealing with masking tape.

7.2.5.4 Allow the specimen to dry face down for 24 h (do not stack specimens during drying). Be certain to clean up the brush or other utensils used to apply the adhesive. Wipe the solvent and any excess adhesive off the brush with a piece of cloth before gluing the next specimen. After 24 h have elapsed, remove all the pieces of masking tape and trim off the four flaps down to the indicated offset mark so that only the 10 mm glued-down portion is left. Trim any fabric protruding below the bottom edge of the forming block.

7.2.6 *Preparing the Aluminum Foil*—Cut an over-sized piece of aluminum foil. If the foil has a shiny and a dull side, place the shiny side face up. The actual specimen is slightly larger than the forming block, depending on the thicknesses of the fabric and interliner (if present). Shape the aluminum foil for the final specimen according to either 7.2.6.1 or 7.2.6.2.

7.2.6.1 Use a fabric-covered forming block encased with the fabric shell top side up. Place the block on the aluminum foil. Hold the block firmly in place and pull each side of the foil up to create the bottom folds. Form the corners by holding the foil firmly in contact with the corner of the specimen. Stretch the corner of the foil and make a 45° fold at each corner. Finally, pull the corners flat against the two sides of the specimen and pat all sides down flat against the specimen. Fig. 2 illustrates the folds to be made. Make sure that the bottom edges and the corners are crisp, straight, and smooth. Remove the forming block and its encasing fabric shell from the foil cup.

7.2.6.2 Set aside one forming block specifically for shaping the aluminum foil containers. Either prepare another block with dimensions 102 by 102 mm (rather than 98 by 98 mm), or glue or tape cardboard to the sides of a block to create one that is 102 by 102 mm. Then use this new block for shaping the aluminum foil as described in 7.2.6.1.

7.2.7 *Assembling the Shell of Resilient Padding and Fabric:*

7.2.7.1 Remove the forming block from the fabric shell. If bits of adhesive make the fabric stick to the block, use a chemist's spatula or a similar dull, knife-like device to loosen the corners. It is easiest to release the fabric by grabbing along the top edge of the fabric between the thumb and the index finger. Remove any adhesive which may remain stuck to the forming block. Make certain that the blocks of resilient padding are identified and tracked according to their masses, which have already been recorded.

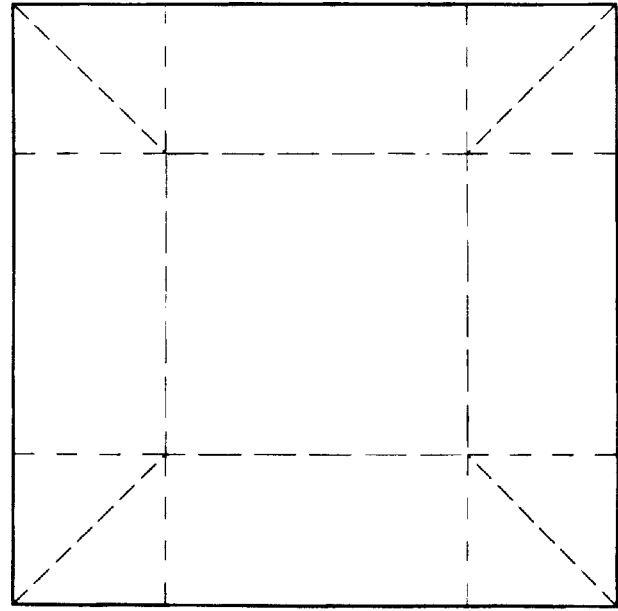


FIG. 2 Folding of Foil

7.2.7.2 Compress the four corners of the selected resilient padding block slightly with the fingers and insert the block into the fabric shell. Make sure that the resilient padding is inserted straight. Check each of the resilient padding block corners to see that they line up exactly at the corners of the fabric shell. Check the top face to see that the block of resilient padding is inserted fully into the shell and that there are no gaps. Also check that the bottom of the resilient padding is neatly lined up with the bottom edge of the fabric. If the specimen construction involves additional padding layers or different padding layers, follow similar steps to ensure that a straight, taut assembly is made.

7.2.7.3 Carefully inspect the specimen. There shall be no buckles, warping, twisting, pulling, etc. The fabric shall be taut and there shall not be any air spaces between the fabric and the padding. If any such problems are discovered and cannot be corrected, discard the specimen. Staple each of the four sides as shown in Fig. 3. Inspect the top face of the specimen. None of the four tabs are to overhang at the top of the specimen. If there is excess material there, trim it with scissors. Be certain that no holes are made in the specimen while doing the trimming.

7.2.8 *Assembling the Specimen and the Foil*—Put the assembled specimen in the foil cup. Pat the aluminum foil sides down flush against the specimen. Cut the top of the foil to be

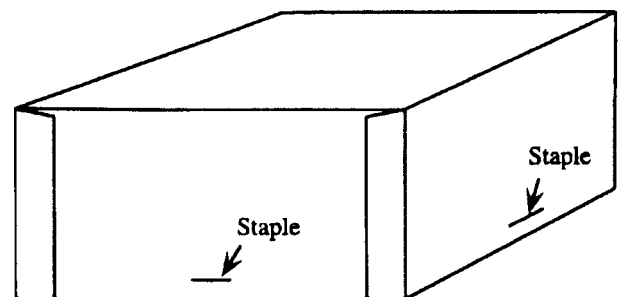


FIG. 3 Assembled Specimen

flush with the top of the specimen. Open up the corners of the aluminum foil slightly and pull the foil top about 20 mm away from the specimen. This will allow good access of air in the conditioning chamber.

7.2.9 Conditioning—Place the specimen in the conditioning chamber for 24 h. Condition to moisture equilibrium (constant mass) at an ambient temperature of $23 \pm 3^\circ\text{C}$ and a relative humidity of $50 \pm 5\%$.

7.2.10 Final Preparation—Remove the specimen from the conditioning chamber. Check that the specimen is wrinkle-free, smooth, and visually completely uniform and symmetrical. Fix or reject the specimen if defects are found. Determine the specimen mass with and without the aluminum foil. Pat the aluminum foil sides again down flush against the specimen. Place the specimen on the sample holder. Gently push down on the top of the specimen, pushing against the ceramic fibre blanket. This ensures that the bottom conforms smoothly to the same bottom conditions as will be seen during the testing. The specimen is now ready to be tested.

7.3 Preparation of Specimens with Multiple Layers and Specialized Constructions:

7.3.1 The following instructions give additional details for preparation of those constructions that involve more than a single fabric layer and a single resilient padding layer. The instructions also provide for some materials which need specialized preparation techniques.

7.3.2 Specimens That Use a Separate Interliner Layer:

7.3.2.1 Specimens that use a separate interliner layer are prepared according to the instructions above, but with the following special provisions. For these composites, the forming block is covered twice, first with the interliner and then with the fabric, using the following steps. Some interliners are mechanically quite fragile. Avoid tearing them when the masking tape is stripped off. Test the tape to be used first to make sure that it can be smoothly pulled off of the interliner without damage.

7.3.2.2 Select an alternate tape or use paper strips if needed. Cut the interliner using the same method as described for cutting fabrics (7.2.4). Glue up the interliner around the forming block using the same instructions as for fabrics (7.2.5). Leave the specimen to dry for 24 h. After 24 h have elapsed, remove all the pieces of masking tape. If there is any interliner protruding below the bottom edge of the forming block, trim such excess off with scissors. The forming block is now covered with a layer of interliner.

7.3.2.3 Once this is done, follow the instructions above for cutting and preparing the fabric. To minimize thickness variations along the completed assembly, when placing the fabric on top of the interliner, turn its orientation by 90° . As a result of this procedure the two sides where the fabric flaps are glued will not line up with the corresponding flaps on the interliner. Thus, two of the sides of the finished specimen will contain doubled-up areas of fabric flaps and the two remaining sides will contain doubled-up areas of interliner flaps. After this procedure continue on to 7.2.6.

7.3.3 Specimens That Use a Polyester Fibre Topper Layer on Top of the Foam:

7.3.3.1 If a polyester fibre batting layer is present over the

top of the foam, the padding assembly is prepared in accordance with 7.3.3.2 or 7.3.3.3.

7.3.3.2 If the uncompressed polyester fibre layer is 20 mm thick or less, it shall be compressed to one half of that thickness in the final assembly. The foam block thickness is then to be the difference between 50 mm and one half of the uncompressed thickness of the polyester fibre layer.

7.3.3.3 If the uncompressed polyester fibre layer is greater than 20 mm, the polyester fibre layer shall be cut back to give a 20 mm depth, and the preparation continued as above. The polyester topper layer shall be placed on top of the foam block. This composite block shall be used wherever the general instructions refer to actions to be taken on the block of resilient padding.

7.3.3.4 During final assembly of the padding inside the fabric, the polyester plus foam composite block shall be compressed so as to have a total depth of 50 mm when the assembly is finished.

7.3.4 Specimens That Use More Than One Padding Layer (Except Polyester Fibre)—Use any padding layers thinner than 8 mm in their natural thickness. The thickness of each remaining layer (those ≥ 8 mm in thickness) shall be proportioned so that its relative thickness in the remaining specimen depth (50 mm minus the thin layers) is in the same proportion as is found for those layers in the full-scale furniture article. Once the appropriate layers are prepared according to this instruction, they are used in exactly the same way as is the single foam block which forms the basis of the general instructions above.

7.3.5 Specimens from Furniture Items of Unusually Thin Construction:

7.3.5.1 For some furniture items, the total thickness of the entire padding layer is less than 50 mm. Examples include thinly padded chairs and innerspring mattresses. For such items, the padding layer is still tested in a 50 mm depth.

7.3.5.2 To do this requires that two or more layers of padding be stacked together to achieve the required 50 mm depth. When testing cone calorimeter samples that represent known full-scale constructions, the test report shall clearly identify what the maximum thickness of padding found in the full-scale article was when that thickness was less than 50 mm.

7.3.5.3 For specimens where the padding comprises layers of several different materials, yet with a total thickness of less than 50 mm, each layer will be laid-up in an increased thickness so that the total padding thickness is 50 mm and maintaining the ratios of individual layer thickness in the same proportion as occurs in the full-scale article. The layers in the test specimen are to be laid up in the same order as the layers of the furniture item.

7.3.6 Specimens Upholstered in Leather:

7.3.6.1 Upholstered furniture specimens using leather shrink significantly during testing and need restraint against excessive movement. This requires the use of four tie wires. Stainless steel or copper wires of approximately 1 mm diameter and 350 mm long are used for this.

7.3.6.2 The sample is prepared in the standard manner and placed in the sample holder. A tie wire is then looped around the sample and the holder such that it is parallel to, and 20 mm